RESEARCH DEPARTMENT

RECEPTION DISTURBANCES OVER NORTH ATLANTIC PATHS DURING THE YEARS 1947 TO 1954

Report No. K-110

(1956/10)

R.A. Rowden

T.W. Bennington

(R.A. Rowden)

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SUMMARY

The records of reception conditions over North Atlantic paths which are regularly made at Tatsfield have been examined for the eight years 1947 to 1954, with a view to learning something about the effects of ionospheric disturbances upon reception over these paths. The nature of the long-period and seasonal variations in the incidence of such disturbances has been investigated. The mean duration of the 250 reception disturbances examined was found to be 3·1 days, with a maximum duration of 17 days.

Using the superposed epoch method for studying the average conditions during disturbances the relation between the time of start of a magnetic and of a reception disturbance was ascertained, and the variation of $f^{o}_{F_2}$ for average disturbance conditions was also examined. It would appear that the magnetic data, and that for $f^{o}_{F_2}$, may have some warning value of the onset of disturbed reception conditions.

1. INTRODUCTION.

Transmission paths between this country and North America are particularly subject to the effects of ionospheric disturbances, because they traverse a region relatively close to the northern auroral zone. Within this zone ionospheric disturbances are more frequent and violent than in other parts of the northern hemisphere, and thus it is found that transmission paths passing through, or even near, to the zone, are more subject to their disruptive effects than are those traversing more southerly regions.

For many years past the B.B.C. receiving station at Tatsfield has made observations upon the strengths of signals incoming from North American broadcast stations, and from these observations has made regular assessments, for different periods of day, of the quality of reception conditions for the North Atlantic transmission paths. The records of these assessments, which are expressed as "Disturbance Ratings", are therefore continuous over these years, and thus constitute a body of data from which some of the details of reception disturbances can be ascertained. In this report the results of an examination of the records of Disturbance Ratings for the eight years 1947 to 1954 are given, this period covering the decreasing phase of the last sunspot cycle from sunspot maximum (1947) to sunspot minimum (1954).

Though the effects of non-reciprocity in short-wave propagation are probably small, and though the effects of circuit asymmetry have been shown to be small for transmission to and from North America, there is some reason to suppose that the effects of ionospheric disturbances may not be simultaneously similar at the two terminals of a North Atlantic transmission path, because of the irregular manner in which the disturbed ionospheric regions may be disposed relative to the two ends of the path. For this reason no attempt has here been made to correlate the disturbed periods observed at Tatsfield with those which may have been observed in North America. It may be supposed, however, that, though subject to differences in particular, the general nature of ionospheric disturbances and their general effects upon broadcast reception are similar in North America and in this country, so far as the North Atlantic transmission paths are concerned. We may thus assume that the variations in reception from North America observed at Tatsfield apply, in a general way, to the reception of B.B.C. transmissions in North America.

2. NATURE OF IONOSPHERIC DISTURBANCES.

Before proceeding to an examination of the data it may be of interest to detail, very briefly, something of the nature of ionospheric disturbances, in so far as it is known. It should be made clear at this stage that, of the two distinct kinds of ionospheric disturbance which are known to occur, namely the short-lived "Sudden Ionospheric Disturbance" and the relatively long-lived "Ionospheric Storm", only the latter are considered in this report. When, therefore, the terms "ionospheric disturbance" or "reception disturbance" are used it is always in reference to one and the same phenomenon, namely to the long-lived type of disturbance which is associated with a decrease in the ionisation of the F_2 layer of the ionosphere, and which is sometimes called an "Ionospheric Storm".

This type of disturbance originates in the sun, from which, often following upon a sort of cataclysmic eruption, a stream of high-speed corpuscles is discharged into space. The corpuscles are thus emitted, not from the whole disc, but from a discrete region upon it, and the stream takes the form of a cone-shaped jet, with the active solar region at its apex. This solar active region is often associated with a sunspot, particularly during the "increasing" phase of the solar cycle, but after sunspot maximum, during the "decreasing" phase of the cycle, many corpuscular streams appear to originate in solar regions which have no unique distinguishing features. These have been designated by Bartels as "M" regions.

Though the corpuscles constituting it possess individual charges the stream as a whole is neutral. The corpuscles travel through space with a velocity of approximately 1300 to 1600 km/sec, so that they would cover the sun/earth distance in about 32 to 26 hours. If the stream is emitted in a direction such that its axis is normal to the sun's surface, and from a position near the sun's central meridian, then the earth would encounter it after *about* that interval.

As the corpuscles approach the earth they, being electrically charged, are affected by its magnetic field, which sweeps them towards the magnetic poles. The terrestrial effects which they produce are thus more intense in regions surrounding the magnetic poles (the auroral regions) than elsewhere. These effects are of several kinds, viz:

a. Disturbances in the earth's magnetic field (magnetic storms) consisting of abnormal fluctuations in the terrestrial magnetic elements, i.e., horizontal force, vertical force and declination.

b. Disturbances in the ionosphere (ionospheric storms) consisting of abnormal decreases in the critical frequency and increases in the virtual height of the F_2 layer, causing a deterioration in short-wave propagation via that layer (reception disturbances).

c. Displays of the polar aurorae and, in some cases, the setting up of abnormal earth currents.

It is to be noted that all these phenomena are different effects produced by a common cause.

The rotation of the sun upon its axis (it does not rotate as a rigid body) ensures that a given region upon its surface will return to the same relative position with regard to the earth at intervals corresponding to the mean period of rotation. The mean period of the sun's synodic rotation, that is after allowing for the earth's forward motion in its orbit, is 27·3 days. Thus, a corpuscular stream originating in the sun will, if it persists, tend to affect the earth during successive solar rotations at intervals of 27·3 days. This produces a recurrence tendency in the phenomena listed above, having that interval. It has been found, however, that while the corpuscular streams associated with M regions often do persist during many solar rotations and thus produce a strong recurrence tendency in magnetic and ionospheric disturbances, those associated with sunspots do so much less often, and thus produce only a weak recurrence tendency. Furthermore, *magnetic* storms associated with sunspots are usually of the S–C type (sudden commencement) as though they were produced by the sudden beginning of a corpuscular stream, whereas those associated with M regions are more often of the non-S–C type, as though produced by a persistent and long-lived stream. It has not, however, been found possible to distinguish different types of *ionospheric* disturbances in this way, except by reference to their magnetic counterparts.

From the above it may be noted, particularly, that the arrival of a corpuscular stream in the earth's atmosphere will tend to produce a magnetic disturbance and — not necessarily at exactly the same time — an ionospheric disturbance which gives rise to a deterioration in reception conditions.

3. DATA USED.

The aim in this work was firstly to examine the Tatsfield records of reception conditions in order to extract from them any useful details regarding the reception disturbances, and, secondly, to compare them with the relevant magnetic and ionospheric measurements in order to discover the relationship between the magnetic and ionospheric phenomena on the one hand and the deterioration in reception conditions on the other.

The magnetic data used was that issued by the Royal Greenwich Observatory, obtained from the continuous photographic records made at the Abinger Magnetic

Observatory. These describe the variations of the geomagnetic field, firstly in terms of "K" Figures for 3-hourly periods commencing at 0000 GMT and ranging from 0 (quiet) to 9 (highly disturbed) and secondly in terms of a Daily Character Number ranging from 0·0 (quiet) to 2·5 (highly disturbed).

The quality of reception conditions at Tatsfield was, during the period under review, expressed in terms of Disturbance Ratings ranging from 0·0 (Propagation much better than normal) to 4·0 (Blackout). The Ratings used apply to the reception of signals over the North American transmission paths, and are evaluated from assessments of the strengths of incoming signals on the appropriate frequencies. The Disturbance Ratings have been estimated for 6-hourly periods commencing at 0000 GMT, for comparison with the 3-hourly "K" figures, and the daily mean Disturbance Rating has been used for comparison with the Abinger Daily Character Number.

TABLE 1

Radio Disturbance Ratings and Magnetic Character Figures

Tatsfield Disturbance Rating		Abinger Daily Character Number		Abinger 3-hourly "K" Figure	
Rating	Definition	Number	Definition	Figure	Definition
0·0	Propagation much better than normal	0·0	Quiet	0·0	Quiet
0·5	Propagation better than normal	0·2		0·2	
1·0	Undisturbed	0·5		1·5	
1·5	Slightly disturbed	0·9		3·5	
2·0	Moderately disturbed	1·4		6·0	
2·5	Considerably disturbed	1·7		7·0	
3·0	Severely disturbed	2·0		8·0	
3·5	Very severely disturbed	2·3		8·5	
4·0	Blackout	2·5	Highly disturbed	9·0	Highly Disturbed

There is no established rule of equivalence between the magnetic and the radio disturbance figures, and, since their total ranges are not the same it is difficult to relate them exactly. It is to be noted that the range of variation usually covers only the middle values, and that extreme values are rather seldom reached in the case of the magnetic figures, and hardly ever in the case of the radio disturbance figures. It is therefore only on the basis of experience that the equivalence has, for the present purpose, been arbitrarily fixed. This is given in Table 1, for every 0·5 value of the Disturbance Rating scale. A significant degree of disturbance is considered to be indicated by a Daily Character Number $> 1{\cdot}0$, by a 3-hourly "K" Figure $> 4{\cdot}0$ or by Disturbance Rating $> 1{\cdot}6$. However this is modified when taking mean values for long periods, as will be explained later.

The ionospheric data used in this report was obtained from the measurements of $f^{o}F_{2}$ made at Slough. The "daily character" of the critical frequency was obtained

by taking the sum of the values of $f^{o}F_2$ for certain hours at equal intervals throughout the 24 hours. This was then compared with the sum of the monthly median values for the same hours, in order to obtain $\Delta f^{o}F_2$, the deviation of the "daily character" value from the monthly median value.

4. ANALYSIS OF RESULTS.

4.1. Long Period Variation in Disturbance.

Because of the fact that ionospheric and magnetic disturbances have their origin in the sun it would be expected that their incidence would show some correlation with solar activity, and, in particular, with the sunspot number. The number of days during each of the years 1947 to 1954 when the Abinger Daily Character Number was $\geqslant 1{\cdot}1$ and the daily mean of the Tatsfield Disturbance Ratings was $\geqslant 1{\cdot}7$ was counted, these being respectively considered to be days of magnetic disturbance and of disturbed reception conditions. The results are given in Fig. 1, where the dotted curve gives the annual mean value of the sunspot number, the dashed curve the percentage of days during each year when disturbed magnetic conditions prevailed and the full-line curve the percentage of days for disturbed reception conditions.

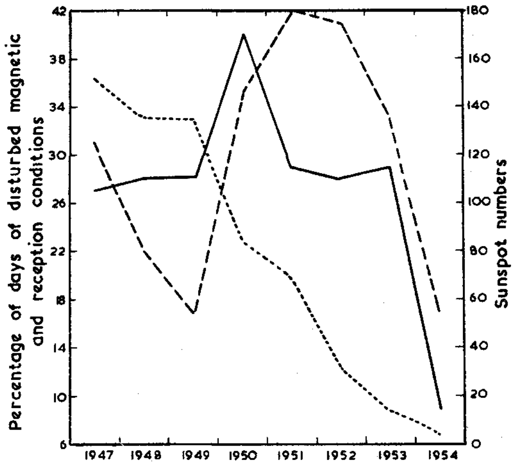

Fig. 1 - Variation in disturbed conditions over eight years showing (full curve) percentage of days of disturbed reception, (dashed curve) percentage of days magnetically disturbed and (dotted curve) annual mean sunspot number

The solar activity decreased during the period from the sunspot maximum (1947) to sunspot minimum (1954). The magnetic disturbance, which was decreasing for the first three years, underwent a sharp increase in 1950, reached a peak in 1951, remained high until 1953, and then underwent a sharp decrease. These variations may, in general, be attributed to the following reasons. During the first three years of the declining solar activity there was a decrease in the number of magnetic disturbances often associated with sunspots (usually of the S-C type), but after 1949 there was, as is usual during the "decreasing" phase of the cycle, a big increase in those attributed to solar M regions (usually of the non-S-C type) and this M region activity lasted until the year before sunspot minimum, when it subsided. In 1954, therefore, there being neither many sunspots nor many M regions to give rise to disturbances, the magnetic disturbance sharply diminished. It would have been expected that the Tatsfield figures for disturbed reception days would have shown the same features as those for the magnetic disturbance, but in fact they do so only weakly. There was no diminution in reception disturbance during the first three years after sunspot maximum, there was a considerable increase in it during 1951 due to the increase in M region activity, but from then until 1953 it remained at a lower, though still high, value. There was,

however, a very sharp decrease in reception disturbance in 1954, in synchronism with those in M region activity and in magnetic disturbance. All that can be said therefore is that reception disturbance remains at a relatively high level throughout the "decreasing" phase of a solar cycle, until just before the minimum, when it decreases to an exceptionally low level.

4.2. Seasonal Variation in Disturbance.

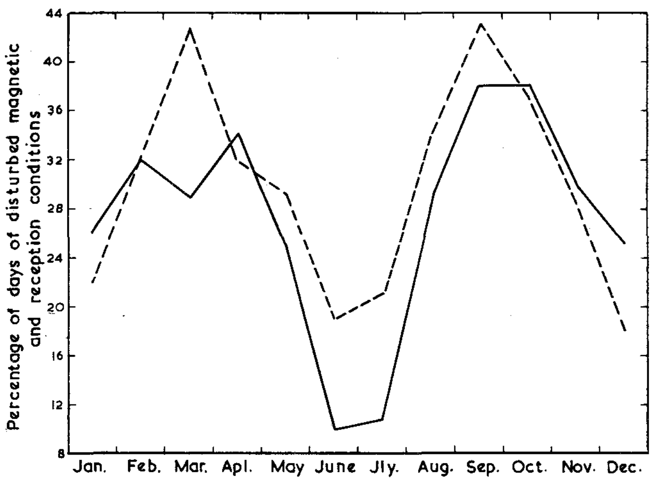

Fig. 2 - Seasonal variation in disturbed conditions. Mean monthly values for eight years 1947-1954, showing (full curve) percentage of days disturbed reception and (dashed curve) percentage of days magnetically disturbed

The magnetically disturbed days and those for reception disturbance (as defined in the previous section) were next taken out month by month for the eight years, in order to discover the seasonal variation in disturbance. The mean monthly percentage of disturbed days for the whole period is plotted in Fig. 2. In the case of magnetic disturbances there is a strongly marked seasonal variation such that almost equally low values of disturbance occur in mid-winter and mid-summer, with higher values at other times of year and peak values during the equinoctial months of March and September. This is a well known result and is ascribed to the fact that at the equinoxes the line joining the centre of the sun and the earth passes through the most active solar regions, which lie somewhat north and south of the solar equator. Corpuscular streams originating in them will therefore be emitted in a direction most likely to encounter the earth at these seasons. At other times of year the active solar regions will be somewhat off the sun/earth line, and their terrestrial effects will be less frequent, and, perhaps, less intense.

The reception disturbances also show a strongly marked seasonal variation of a form somewhat similar in character to that of the magnetic disturbances. However there are differences, for, whilst reception disturbance is also at a peak around the equinoxes, there is a less marked decrease in mid-winter and a more strongly marked decrease in mid-summer, than in the case of magnetic disturbances. Reception disturbance thus has a relatively high value in winter, a peak value in periods of two to three months surrounding the equinoxes, and a very low value in mid-summer. This may be explained by the fact that the severity of a reception disturbance is conditioned, not only by the intensity of the corpuscular stream, but by the normal value of the F_2 ionisation. Thus during the winter, when this ionisation is very low for a large part of the day, a stream of given intensity will have more effect in causing a deterioration in reception than during the summer, when the ionisation does not fall to such low diurnal values.

It will be noted from Figs. 1 and 2 that the percentages of magnetically disturbed days do not often coincide with those for reception disturbances, the implication being that the two types of disturbance do not necessarily occur in synchronism, or do not have the same duration time.

4.3. Duration of Disturbance.

During the eight years under review there were, according to the definitions of magnetic and reception disturbance given above, 250 periods of continuous reception disturbance (on a daily basis) and 352 similar continuous periods of magnetic disturbance. The number of periods of reception disturbance was the same as that of magnetic disturbance during the winters, but during the equinoctial and summer seasons the number of magnetic disturbances exceeded that of the reception disturbances. Details regarding the duration of the disturbances for the whole eight years are given in Table 2, in which the months of March, April, September and October have been considered to be equinoctial months.

TABLE 2

	Reception Disturbances Days	Magnetic Disturbances Days
Duration of longest disturbance	17·0	19·0
Duration of shortest disturbance	1·0	1·0
Mean duration of disturbances	3·1	2·4
Mean duration of disturbances (winter only)	2·8	2·4
Mean duration of disturbances (equinox only)	3·8	2·7
Mean duration of disturbances (summer only)	2·7	2·2

Thus the reception disturbances were, on the average, slightly longer-lived than the magnetic disturbances, and it seems that the former sometimes persist after the magnetic conditions become quiet. It is interesting to note that, though, as shown in Fig. 2, the percentage of days of reception disturbance was greatest at the equinoxes, the actual number of disturbances was greatest in winter. This was not the case for the magnetic disturbances, however, for they occurred most frequently at the equinoxes.

The most prolonged disturbance, both magnetically and for reception conditions, occurred in September 1951, and, since this may be of interest as an example, the conditions during this disturbance have been plotted in Fig. 3, in terms of the Abinger Daily Character Numbers and the Tatsfield mean daily Disturbance Ratings, the horizontal line representing the arbitrarily fixed disturbance level. In this case reception conditions did not become seriously disturbed until the third day after magnetic conditions had reached the disturbed level. They then remained continuously disturbed (on a daily basis) for seventeen days, falling below the disturbance level one day after the magnetic conditions had done so. The disturbance is seen to have been one which gradually built up, the peaks of magnetic disturbance occurring on the eleventh and sixteenth days after its start and the peak of reception

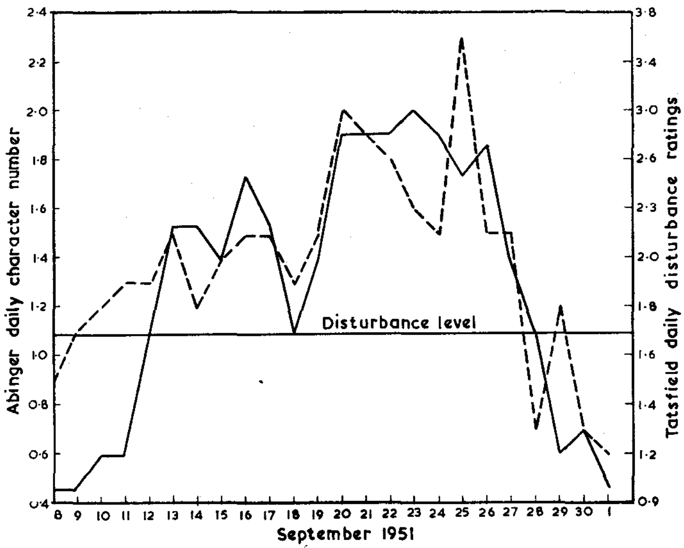

Fig. 3 - Example of a prolonged disturbance-magnetic conditions (dashed curve) were continuously disturbed, on a daily basis, for 19 days and reception conditions (full curve) for 17 days

disturbance on the fourteenth day after the start of the magnetic disturbance, and the eleventh after the start of the reception disturbance. After the peak period both types of disturbance subsided more rapidly than they had built up. It may be added that only 18 of the 250 disturbed reception periods exceeded seven days duration: an average of just over two per year.

4.4. Further Details of Disturbances.

The *average* conditions prevailing during disturbances were studied by plotting the data according to the superposed epoch method. For this purpose it was considered sufficient to take a sample from the disturbances which occurred during the eight years, and accordingly all the disturbances which occurred during 1952 and 1953 were used. Considered on the basis of the magnetic measurements only there were 61 separate disturbances during this period, it being thought necessary for the Numbers to fall appreciably lower than the disturbed value in order to mark the end of a disturbed period. Each disturbance was considered to start on the day when the Abinger Daily Character Number first exceeded 1·0, this day being called zero day. The epoch then considered was from −2 to + 8 days with respect to zero day, and the data for all 61 such epochs was superposed, and the means taken. The result is plotted in Fig. 4.

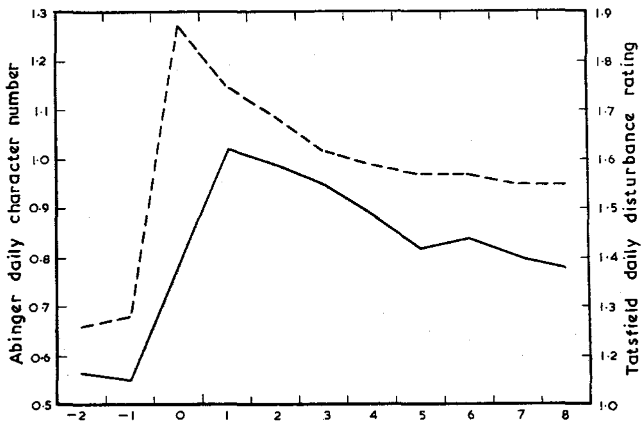

Fig. 4 - Means of Daily Disturbance Ratings (full curve) and of Daily Magnetic Character Numbers (dashed curve) for westerly paths for all disturbances 1952/53 (61 disturbances)

It is pointed out that averaging the data for a large number of disturbances in this way results in an alteration of the disturbed level datum line as used in Fig. 3, because of the different duration times of the disturbances and of the fact

that zero day for both magnetic and reception disturbances may not coincide. In fact no precise disturbance level can be established: nevertheless the average variation of conditions during disturbances is clearly shown.

The most important points from Fig. 4 are that whilst, on the average, the peak of the magnetic disturbance occurs on the first disturbed day, reception conditions on that day become only moderately disturbed, and do not reach a peak of disturbance until the following day. This seems to confirm the general experience of short-wave engineers, i.e., that reception conditions often continue to deteriorate for a considerable time after a magnetic disturbance begins to subside. It is seen that, within the period of eight days after the start of a disturbance neither the magnetic nor the reception conditions have reached their low pre-disturbance values. This, however, is somewhat misleading, and is occasioned by the fact that new disturbances often follow on the first within a lesser period than eight days.

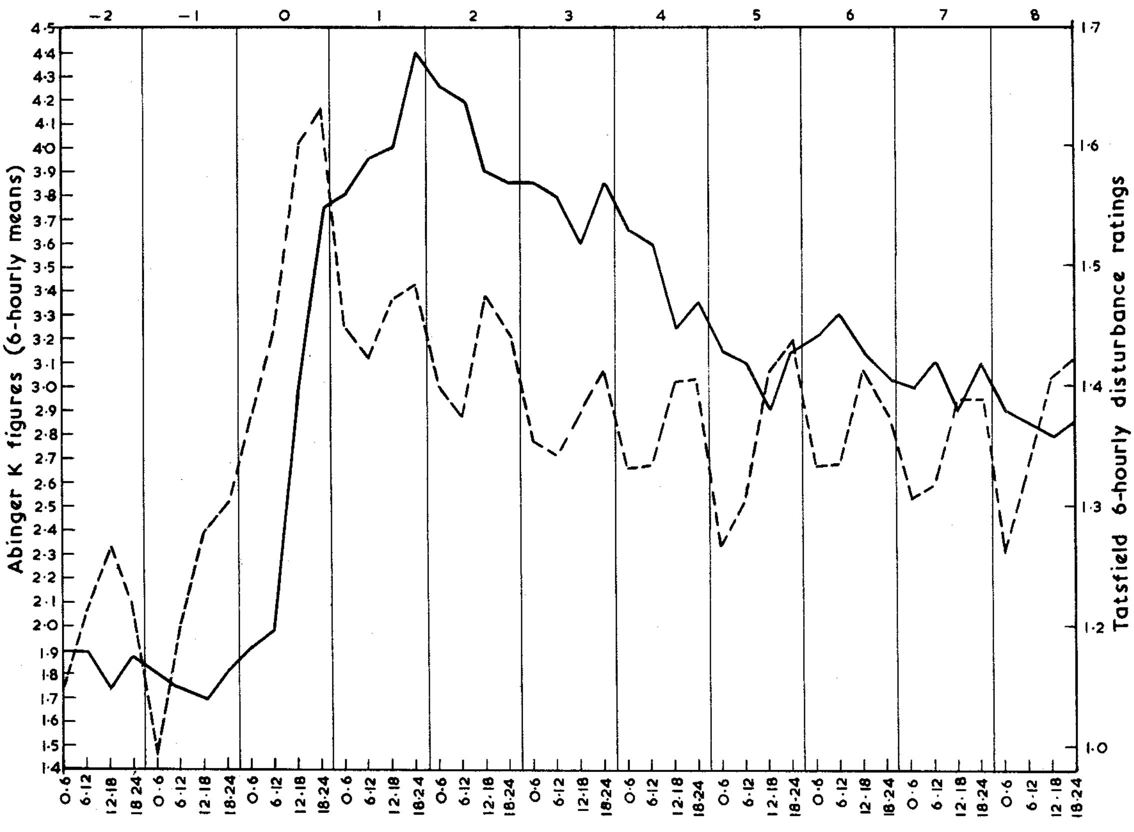

Fig. 5 - Mean values of Tatsfield 6-hourly disturbance ratings (full line) and of Abinger 6-hourly "K" figures (dashed line) for all storms 1952/53 (61 disturbances)

The average variation of conditions during disturbances is shown in more detail in Fig. 5, in which the data for the same sample of 61 disturbances has been plotted, using the superposed epoch method, on a 6-hourly basis (the minimum period for which Disturbance Ratings are given). For comparison with the Disturbance Ratings the 3-hourly Abinger "K" Figures have been used, a mean of two 3-hourly values being taken as representing magnetic conditions for each 6-hour period. As before,

it is not possible to define a precise disturbance level because of the averaging, but it would seem reasonable to take a "K" figure of 3·0 and a disturbance rating of 1·4 as indicative of this. It would then appear that, whilst magnetic conditions may have reached a significant level of disturbance during the period 0600 to 1200 LT on the first day of the disturbance, reception conditions were, during that period, hardly at all disturbed, and did not become significantly so until the period 1200 to 1800 LT of the first day. Though this result does not exactly coincide with findings regarding the time of the start of ionospheric storms obtained from different data, it does at least strongly indicate that there is, on the average, some lapse of time between the incidence of disturbed magnetic conditions and that of the disturbed reception conditions which usually accompany them. This time would, in fact, appear to be from 3 to 6 hours. If this is indeed so then it is a convenient feature of the disturbances which might be put to use by short-wave engineers, for it means that the incidence of disturbed magnetic conditions is often a precursor of disturbed reception conditions.

It will be noticed, also, that whilst the peak value of magnetic disturbance occurs, on the average, during the period 1800 to 2400 LT on the first day, that for the reception disturbance does not occur until the period 1800 to 2400 on the following day. It is also indicated that reception conditions remain disturbed, on the average, for a longer period than do magnetic conditions.

4.5. Diurnal Variations in Disturbance.

It will be noticed, from Fig. 5, that there is a marked diurnal variation in the magnetic disturbance, or rather in the value of the Abinger "K" figure, which is not apparent in the reception disturbance ratings. This is a well-known feature of the magnetic variation due to disturbance, which is of a character such as to produce higher values in the post-meridian than in the ante-meridian period.

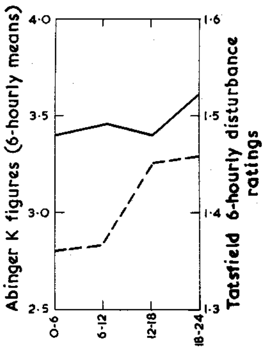

Fig. 6 - Daily variation in reception disturbance and magnetic disturbance for all disturbances 1952/53 (61 disturbances) Means of "K" figures (dashed line) and Disturbance Ratings (full line) for superposed daily epochs

In order to clarify these matters all the daily epochs shown in Fig. 5 for day 0 to day 6 inclusive (the most disturbed periods) were superposed one upon the other, and the means taken. This brings out the mean daily variations in both magnetic and reception disturbance, and the result is given in Fig. 6. It is seen that, whilst the magnetic disturbance is considerably greater in the period 1200 to 2400 LT than in the period 0000 to 1200 LT there was little diurnal variation in the degree of reception disturbance, beyond a slight increase during the period 1800 to 2400 LT.

5. IONOSPHERIC VARIATIONS DURING DISTURBANCES.

Since reception disturbances are due to the failure of radio propagation in the ionosphere during the times when it is affected by the solar corpuscular streams it is of interest to examine the ionospheric data obtained at these times to see whether it reflects the effects of the disturbances.

The ionospheric layer involved in transmission between North America and this country is the F_2 layer, and it would be expected that the ionisation of this layer would decrease during the disturbances, and hence that its critical frequency would show a downward deviation from its normal value.

It was thought useful, first, to examine the f^oF_2 variations during a single disturbance, and for this purpose the prolonged disturbance of September 1951 was selected. For comparison with the daily mean value of the Tatsfield Disturbance Ratings a daily sample of f^oF_2 at Slough was taken for each of the days 8th September to 1st October, this being the sum of the measured values for every third hour commencing at 0000 GMT. This was compared with the sum of the monthly median values for the same hours, in order to obtain Δf^oF_2, the daily percentage deviation from the monthly median value. In Fig. 7 are plotted the values of Δf^oF_2 and of the Tatsfield mean daily Disturbance Rating for each day, the disturbed value of 1·7 in the latter being arbitrarily made equivalent to a negative deviation of 10%, and the values being plotted with ascending order downwards on the ordinate, so as to correspond with a negative deviation of f^oF_2.

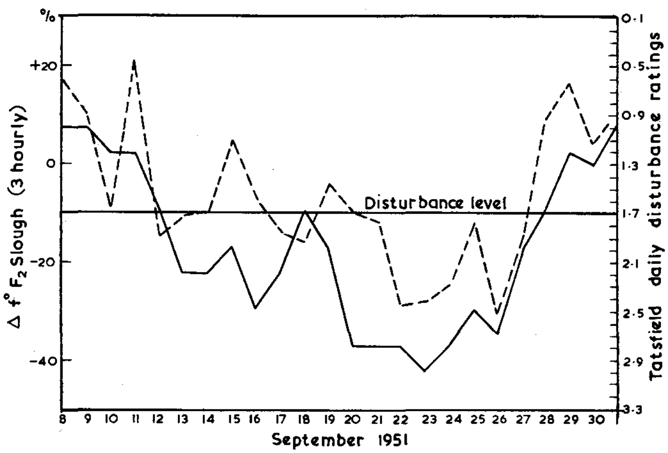

Fig. 7 - Daily variation of Tatsfield Disturbance Rating (full line) and of Slough Δf^oF_2 (3-hourly values)(dashed line) during prolonged disturbance of September 1951

The correspondence between the daily Δf^oF_2 and reception disturbance is not very strong, there being large day-to-day fluctuations in the former. However, on 11th (the day before reception conditions became disturbed) it had a particularly large positive value, which may have been due to the disturbance having an initial positive phase. From 12th to 27th, during the whole of which time disturbed reception conditions prevailed, it generally had a negative value, which was greatest at about the time that reception conditions were most disturbed. Positive values were reached on 28th, the same day on which the disturbance rating returned upwards to the disturbance level. The deviations of f^oF_2 at Slough do in general, therefore, have a negative value during the time when disturbed conditions for the reception at Tatsfield of stations in North America prevail.

In order to examine the *average* ionospheric conditions during disturbances the data for Δf^oF_2 was plotted against that for reception disturbance using the superposed epoch method. In this case a sample of 27 disturbances was taken, i.e., all those which were recorded during 1953. As before zero day was considered to be the day when the Abinger magnetic Daily Character Number first exceeded 1·0, and the epoch considered was from −2 to + 8 days. The "daily character" of the critical

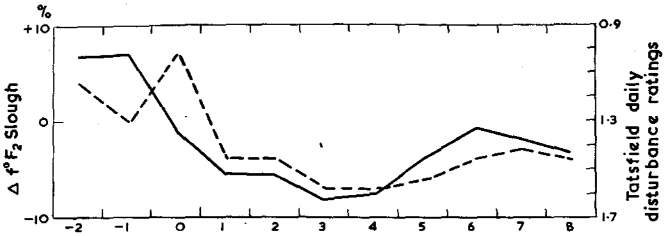

Fig. 8 - Means of Tatsfield Daily Disturbance Ratings (full curve) and of $\Delta f^{\circ}_{F_2}$ Slough (6-hourly values) (dashed line) for all disturbances 1953 (27 disturbances)

frequency at Slough was obtained for each disturbed day by taking the measured $f^{\circ}_{F_2}$ for every sixth hour commencing at 0000 GMT, and obtaining the sum of these. The mean value of these sums for each month was obtained and all mean values superposed according to the day in the epoch. The sum of the values for each day in the epoch was then compared with the sum of the monthly median values in order to obtain $\Delta f^{\circ}_{F_2}$, the mean percentage deviation from the median for the 27 epochs, for each individual day. The result is plotted in Fig. 8.

It is seen that from day 1 onwards the value of $\Delta f^{\circ}_{F_2}$, for these average conditions, was negative, i.e., that during this period, when disturbed conditions prevailed, the deviations of $f^{\circ}_{F_2}$ at Slough had an average negative value. Not so on zero day, however, for on that day, when magnetic conditions were already disturbed and reception conditions deteriorating, $\Delta f^{\circ}_{F_2}$ had, for average conditions, a considerable positive value. Because the data is the average of that for 27 zero days it is thought that this result could not be fortuitous.

However, it was thought useful to examine conditions on the zero days a little more closely, and in order to do this the mean values of all data for the 27 zero days of 1953 were taken. This consisted of the mean values of the 6-hourly Tatsfield Disturbance Rating during each 6-hourly period, the mean values of the 3-hourly Abinger "K" Figures for each 3-hourly period and the mean values of $\Delta f^{\circ}_{F_2}$ for each 3-hourly period. The latter was obtained by taking the sum of the $f^{\circ}_{F_2}$ values for each 3 hours, taking the mean value of this for each month, obtaining the sum of the means and comparing this with the sum of the monthly median values for the same 3 hours in order to obtain $\Delta f^{\circ}_{F_2}$, the mean percentage deviation from the monthly mean for each 3-hourly period.

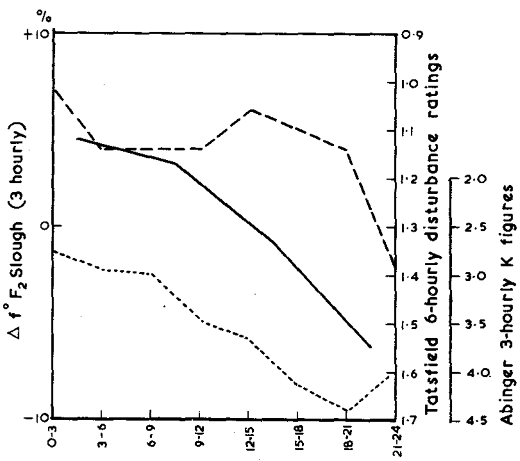

Fig. 9 - Mean variations for 27 zero days of magnetic disturbances. Means of Tatsfield 6-hourly Disturbance Ratings (full line), of Slough 3-hourly $\Delta f^{\circ}_{F_2}$ (dashed line) and of 3-hourly "K" figures (dotted line) for zero days of all disturbances 1953 (27 disturbances)

From Fig. 9, which gives the results, it is seen that, for average conditions on zero days during these 27 disturbances, whilst reception conditions did not reach a disturbed value until the period 1800-2400 LT, magnetic conditions

did so during the 0900-1200 LT period. Disturbed magnetic conditions thus anticipated disturbed reception conditions by a rather longer period than was indicated for the 61 disturbances dealt with in Fig. 5, the time indicated in this case being from 6 to 9 hours. This different result may be due to the fact that a smaller number of disturbances were used in the present case, and it is, in any case, not possible to define precisely the disturbance level. It does however appear that, for average conditions, disturbed magnetic conditions act as a precursor of disturbed reception conditions, and may have a warning period of about 3 to 6 hours. It is interesting to note that the disturbance component in the earth's field reaches its peak value not at 2400 LT, but during the period 1800-2100 LT, at least in this country. This, it is thought, is a well established fact.

Fig. 9 also shows that, for average conditions on zero days of magnetic disturbance, $\Delta f^{o}{}_{F_2}$ at Slough has a positive value during every 3-hourly period until that of 2100-2400 LT, when it attains a negative value and which, as shown in Fig. 8, it maintains throughout the remaining course of the disturbance. This is, no doubt, the so-called positive phase of the ionospheric disturbance. It would seem that the positive value of $\Delta f^{o}{}_{F_2}$, taken together with the increasing value of the magnetic "K" figure, would act as an additional precursor of the coming reception disturbance.

6. CONCLUSIONS.

6.1. The incidence of reception disturbances at Tatsfield remained high during the years of the "decreasing" phase of the solar cycle, until the year of sunspot minimum, when it decreased to a very low value.

6.2. There was a marked seasonal variation in the incidence of reception disturbances, such as to give very low values in summer, relatively high values in winter and maximum values around the equinoxes.

6.3. The disturbances varied in duration from approximately 1 to 17 days, with a mean duration of 3·1 days. Approximately two disturbances per year exceeded 7 days duration.

6.4. From a study of the average conditions for a sample of 61 of the disturbances it is concluded:

a. Reception conditions are only moderately disturbed on the first day of a magnetic disturbance, when the magnetic disturbance is most intense, and do not reach a peak of disturbance until the following day.

b. Magnetic conditions reach a significant degree of disturbance, on the average, from about 3 to 6 hours before reception conditions become significantly disturbed.

c. Reception conditions tend to remain disturbed for a period after magnetic conditions have become quiet.

d. There is little diurnal variation in the degree of reception disturbance beyond a slight increase in the period 1800-2400 LT.